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THESIS

FORECASTING ADVANCEMENT RATES TO PETTY OFFICER THIRD CLASS FOR U.S. NAVY HOSPITAL CORPSMEN

by

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June 2014

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We develop forecasting models to identify the most influential decision variables in predicting advancement probabilities to petty officer third Class (E-4) in the Hospital Corpsman rating in the U.S. Navy. Analyzing a Sailor's first three opportunities at advancement to E-4, the possible outcomes are advancement, failure to advance, or separation from the Navy between advancement opportunities. Using data collected from 1996 through 2004, on more than 50,000 Sailors in this rating, multivariate logistic regression models are developed to estimate Sailors' advancement probabilities based on their individual personal and professional attributes.

We find that the three corresponding models developed are nearly identical with respect to the influences of year of promotion, length of service, Navy enlisted classification code, the total number of sea months, the proportion of vacancies to test takers, Armed Forces Qualification Test score, and performance mark average (PMA). Among the variables considered, PMA is found to be the most influential in predicting a Sailor's estimated advancement probability, supporting the hypothesis that "sustained superior performance" is the key to success in a military career.

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FORECASTING ADVANCEMENT RATES TO PETTY OFFICER THIRD CLASS FOR U.S. NAVY HOSPITAL CORPSMEN

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ABSTRACT

We develop forecasting models to identify the most influential decision variables in predicting advancement probabilities to petty officer third class (E-4) in the Hospital Corpsman rating in the U.S. Navy. Analyzing a Sailor's first three opportunities at advancement to E-4, the possible outcomes are advancement, failure to advance, or separation from the Navy between advancement opportunities. Using data collected from 1996 through 2004, on more than 50,000 Sailors in this rating, multivariate logistic regression models are developed to estimate Sailors' advancement probabilities based on their individual personal and professional attributes.

We find that the three corresponding models developed are nearly identical with respect to the influences of year of promotion, length of service, Navy enlisted classification code, the total number of sea months, the proportion of vacancies to test takers, Armed Forces Qualification Test score, and performance mark average (PMA). Among the variables considered, PMA is found to be the most influential in predicting a Sailor's estimated advancement probability, supporting the hypothesis that "sustained superior performance" is the key to success in a military career.

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TABLE OF CONTENTS

LIST OF FIGURES

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LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

AFQT	Armed Forces Qualification Test
ASVAB	Armed Services Vocational Aptitude Battery
BIC	Bayesian information criterion
BUPERS	Bureau of Naval Personnel
CCC	command career counselor
DEP	Delayed Entry Program
E-1	seaman recruit
E-2	seaman apprentice
E-3	seaman
E-4	petty officer third class
E-5	petty officer second class
E-6	petty officer first class
E-7	chief petty officer
E-8	senior chief petty officer
E-9	master chief petty officer
FMS	final multiple score
GED	General Educational Development
HA	hospitalman apprentice
H-L	Hosmer-Lemeshow
HM	hospital corpsman
HM1	hospital corpsman first class
HM2	hospital corpsman second class
HM3	hospital corpsman third class
HMC	chief hospital corpsman
HMCM	master chief hospital corpsman
HMCS	senior chief hospital corpsman
HN	hospitalman
HR	hospitalman recruit
HYT	high year tenure
LOS	length of service

METC	Medical Education and Training Campus
NEC	Navy enlisted classification
NPC	Naval Personnel Command
NPRST	Navy Personnel Research, Studies, and Technology
PMA	performance mark average
PNA	pass not advanced
RTC	recruit training command
SIPG	service in pay grade
TAFMS	total active federal military service
TIR	time in rate

EXECUTIVE SUMMARY

As of 2014, the U.S. Navy enlisted force is comprised of approximately 279,000 Sailors in more than 50 active skill sets (“ratings”). In order to manage staffing levels across the various ratings, forecasting models are utilized to predict advancement rates, and help set numerical targets for future advancement cycles. This study focuses on Sailors in the Hospital Corpsman (HM) rating eligible for advancement to petty officer third class (E-4). This rating is of particular interest because of its importance to the Navy in fulfilling its missions, as well as the substantial investment made by the Navy to develop the requisite skills of these Sailors. Additionally, advancement to E-4 is analyzed because it is the first pay grade to which Sailors are advanced based on their performance and evaluations, vice solely meeting minimum time requirements.

Using data collected from 1996 through 2004, and consisting of 50,629 Sailors between the rates of seaman (E-3) and chief petty officer (E-7) in the HM community, we develop forecasting models for advancement to E-4. To accomplish this, a subset of the data on Sailors who are eligible for advancement to E-4 is extracted, with individual Sailors analyzed up to their first three opportunities at advancement. During this time, the following outcomes are possible: advancement to E-4 on their first, second, or third opportunity; failure to advance; or separation from the Navy in between advancement opportunities.

In the performance of this study, multivariate logistic regression models are developed that identify the most influential variables in predicting advancement rates to E-4. From these models we obtain estimates of Sailors’ advancement probabilities based on their individual personal and professional attributes. Specifically, this study answers the following questions:

1. For analyzing a Sailor’s first three looks at advancement to E-4, are there substantial differences between the three models? If so, what are the differences?
2. What are the most influential predictor variables in determining probabilities of advancement to E-4?

3. Is prior advancement success a good indicator of future success? Specifically, does knowing on which attempt a Sailor makes E-4 provide any insight on whether or not they will advance to the rate of petty officer second class (E-5; HM2)?

We find that the three corresponding models developed for advancement to E-4 are nearly identical with respect to the influences of year of promotion, length of service, Navy enlisted classification code, the total number of sea months, the proportion of vacancies to test takers, Armed Forces Qualification Test score, and performance mark average (PMA). Among the variables considered, PMA is found to be the most influential in predicting a Sailor's estimated advancement probability, supporting the hypothesis that "sustained superior performance" is the key to success in a military career.

To determine whether the number of attempts a Sailor requires to advance to E-4 provides a useful indication on his or her probability of advancement to E-5, multivariate logistic regression models are developed for a Sailor's first three advancement opportunities to E-5. Included in the analysis is the categorical variable that identifies on which advancement opportunity a Sailor advances to E-4. This additional variable is not found to be statistically significant for inclusion in any of the E-5 advancement models; indicating the data does not support the hypothesis that knowing the required number of attempts for advancement to E-4 is a good indicator in predicting estimated advancement probabilities to E-5.

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I. INTRODUCTION

A. MOTIVATION AND OBJECTIVES

As of 2014, the U.S. Navy enlisted force is comprised of approximately 279,000 Sailors in more than 50 active skill sets ("ratings"). In turn, the Navy requires these Sailors to possess a spectrum of skills at adequate levels of staffing in order to fulfill its missions. In order to manage staffing levels across the various ratings, the Navy uses forecasting models to predict advancement rates and to help set numerical targets for future advancement cycles. This thesis considers the problem of forecasting advancement rates for U.S. Navy enlisted Sailors in the medical community, which requires skills that are valued both in the Navy and in the civilian economy. This rating is of particular interest not only because of its importance to the Navy in fulfilling its missions, but also because of the substantial investment made by the Navy, both monetarily and in man-hours, to develop the requisite skills of its Sailors.

Specifically, using data collected from 1996 through 2004, and consisting of 50,629 Sailors between the rates of seaman (E-3; HN) and chief petty officer (E-7; HMC) in the Hospital Corpsman (HM) rating, this thesis seeks to develop advancement forecasting models to the rate of petty officer third class (E-4; HM3). Advancement to E-4 is of particular interest because it is the first pay grade in which Sailors are advanced based on their performance and evaluations, rather than solely meeting minimum time requirements. To accomplish this, a subset of the data is extracted consisting only of Sailors eligible for advancement to E-4. For this group, individual Sailors are analyzed for up to their first three "looks" (if necessary) at advancement, during which time they experience one of the following outcomes: selection to E-4 on their first, second, or third opportunity; failure to advance; or separation from the Navy between looks.

In the performance of this study, conditional analysis is conducted in order to produce models that identify predictor variables that are influential to advancement and

early-on success during a Sailor's military career. Additionally, we seek to establish and apply modeling methodologies that can be used in future force structure shaping and advancement forecasting models.

B. THE PROCESS OF BECOMING A HOSPITAL CORPSMAN IN THE U.S. NAVY

Of the more than 50 active ratings in the Navy, The HM community is the most populated with over 17,000 Sailors as of 2014. The mission of the HM community is described as follows:

> Hospital Corpsmen perform duties as assistants in the prevention and treatment of disease and injury and assist health care professionals in providing medical care to Naval personnel and their families. They may function as clinical or specialty technicians in over 38 occupational specialties, medical administrative personnel and health care providers at medical treatment facilities. They also serve as battlefield corpsmen with the Marine Corps, rendering emergency medical treatment to include initial treatment in a combat environment. Qualified Hospital Corpsmen may be assigned the responsibility of independent duty aboard ships and submarines; Fleet Marine Force, Special Forces and Seabee units, and at isolated duty stations where no medical officer is assigned. (Naval Personnel Command (NPC), n.d., Hospital Corpsman: General Description, para. 1)

> Hospital Corpsman Dental Assistants performs duties as a general dental assistant to include infection control, dental treatment room management, preventive dentistry, comprehensive dental assisting, and intraoral radiography. (NPC, n.d., Hospital Corpsman: General Description, para. 2)

For an individual interested in joining the ranks of the HM community in the U.S. Navy, the first step is to be accepted into military service and meet the qualification requirements for the HM rating. In order to do this, he or she must take the Armed Services Vocational Aptitude Battery (ASVAB), which is a multiple-aptitude series, consisting of nine individual exams. The ASVAB "measures developed abilities, and helps predict future academic and occupational success in the military. It is administered annually to more than one million military applicants, high school, and post-secondary students" (ASVAB, n.d., para. 1). Upon completion of the ASVAB, the individual's Armed Forces Qualification Test (AFQT) score is calculated from the following

individual ASVAB tests: Word Knowledge, Paragraph Comprehension, Arithmetic Reasoning, and Mathematics Knowledge. An individual must receive a minimum AFQT score of 35 (max score is 99) to be eligible for service in the U.S. Navy. Additionally, individuals interested in joining the HM community must receive a collective score of 156 on the following ASVAB exams: General Science, Mathematics Knowledge, Word Knowledge, and Paragraph Comprehension.

With the AFQT and ASVAB requirements having been met, a recruit must then negotiate his or her orders to reflect whether or not they want to specialize in the field of dentistry within the HM community. Having made this decision and negotiated orders, the recruit is then assigned to basic training ("boot camp") at Recruit Training Command (RTC), located at Naval Station Great Lakes, Illinois. Basic training is an eight-week long program, which seeks to supply "the fleet with top-quality basically trained Sailors ready for follow-on training" (RTC, n.d., para. 1).

Upon completion of basic training, Sailors who have been selected for the HM rating proceed to Joint Base San Antonio, Fort Sam Houston for HM basic training ("A" School), which is conducted at the Medical Education and Training Campus (METC). METC's mission is to "provide support to the Fleet and Navy Medicine by serving as homeport for health care professionals associated with the San Antonio medical training pipelines" (Navy Medical Training Support Center, n.d., para. 4). Annually, the school enrolls approximately 4,300 Sailors, and averages about a 95 percent graduation rate (L. Nazario (METC quota manager), personal communication, March 26, 2014).

At approximately the seven-week mark of "A" school, enrollees begin working with the instructors and command career counselor (CCC) to negotiate their follow-on orders. At that time, and based on funding, availability, timing, and qualification, the CCC presents the current class with the list of job billets and follow-on training available. Follow-on training comes in the form of "C" schools, which train Sailors in a number of advanced and specialized medical jobs, from the more well-known jobs such as physical therapy technician to search and rescue medical technician. Upon completion of "A" and "C" schools, Sailors receive a unique Navy enlisted classification (NEC) code, signifying

graduation from that school and qualification to work in the given field. Currently, there are 38 NECs in the HM community, which are listed in Table 32 in the Appendix.

C. FOCUS OF THE RESEACH

The goal of this thesis is to develop forecasting models that identify the most influential predictor variables in predicting advancement rates to E-4. Our inquiry proceeds as follows: First, exploratory analysis of the data is conducted to identify important data characteristics such as missing or anomalous observations, and to acquire a basic understanding of the relationships between variables. Next, multivariate logistic regression is utilized to construct forecasting models for up to a Sailor's first three looks at advancement to E-4. Finally, model outputs are aggregated and summarized, allowing us to not only predict advancement rates; but also to compare models and to identify similarities across the different looks analyzed.

This study answers the following study questions:

1. For analyzing a Sailor's first three looks at advancement to E-4, are there substantial differences between the three models? If so, what are the differences?
2. What are the most influential predictor variables in determining probabilities of advancement to E-4?
3. Is prior advancement success a good indicator of future success? Specifically, does knowing on which attempt a Sailor makes E-4 provide any insight on whether or not they will advance to the rate of petty officer second class (E-5; HM2)?

D. BENEFITS OF THIS STUDY

Accurate forecasting of advancement is of constant importance to both policy makers and individual Sailors alike. While concentrating on the medical community, this study aims to develop methodologies of forecasting advancement rates and identifying key predictor variables that should be more broadly applicable.

E. ORGANIZATION OF THIS THESIS

Chapter II presents a literature review focusing on previously conducted advancement studies, with particular focus on the methodologies and findings of each

study, and on topics pertinent to the HM community. Chapter III describes the quantitative approach used in this thesis. It includes a description of the data set used for analysis, the variables considered in the analysis, and the analytical methodologies used. Chapter IV presents findings from the analysis used in the final models. Chapter V presents conclusions derived and recommendations for future work based on our analysis and findings.

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II. BACKGROUND

A. LITERATURE REVIEW

This section reviews studies on the forecasting of advancement and related subjects of interest to the HM community. Specifically, studies in the following areas are reviewed: forecasting enlisted advancement, the relationships of education and AFQT scores to advancement, and other topics specific to the HM community.

1. Previous Studies on Enlisted Advancement

An extensive study on enlisted advancement in the U.S. Navy is Golan, Green, and Perloff (2010). Using data that encompass approximately 86 percent of all enlisted Sailors (E-3 through E-7) from 1997 through 2008, the authors develop a multiple-step decision model to represent a Sailor's advancement and retention probabilities by utilizing a probit model with the following predictor variables: AFQT score; education level (non-high school graduate, high school diploma, and post high school); a Sailor's current sea shore rotation; pay grade; race (white, African-American, Hispanic, or other); time, reflecting periods of "peace" and "conflict;" total number of sea months; gender; and the ratio of the number of vacancies and the number of Sailors eligible for advancement in a given cycle. Using these variables, 21 ratings are analyzed, and the results from the administrative group, consisting of 53,556 observations, are presented.

From their analysis, Golan et al. (2010) report several interesting conclusions. They find that Sailors with higher AFQT scores and with post-high school education are more likely to be advanced, as one might expect. Additionally, they show that although a Sailor's chance of advancement is not affected by whether or not they are in a sea-duty station, the total amount of time that a Sailor has spent at sea over their entire career does affect advancement. Interestingly, as the length of sea time a person has initially increases, there is a positive effect on advancement, but once Sailors have spent more than 22 percent of their career at sea, there appears to be an increasingly negative effect on advancement. Also showing a negative effect on advancement probability is pay grade, with higher pay grades having lower advancement probabilities than lower pay

grades, which make sense due to there being fewer available job positions at higher pay grades. Across all racial demographics and pay grades, the authors find that advancement probability decreases significantly (approximately 25 percent across the board) when moving from a period of peace to a period of conflict, defined in this study by being either before September 11, 2001 (peace) or after this date (conflict). The authors note a reduction in advancements tied to the Navy's draw-down during the 1990s, followed by activation of naval reserve forces following 9/11.

Another extensive but earlier study on enlisted advancement is that conducted by Buddin, Levy, Hanley, and Waldman (1992), who consider the advancement tempo of 12,278 Army and 12,490 Air Force enlisted personnel up to the E-5 pay grade, to determine how advancement affects retention. Collected between 1983 and 1989, the data consists of first-term males with four-year enlistments. The authors use maximum likelihood logistic regression models to identify influential variables in predicting advancement tempo. The key variables considered are: educational level, AFQT score, and the times required to make E-4 and E-5 respectively. Prior to reviewing the results of this study, it is important to point out the inherent differences in the advancement policies of these two services. Similar to the Navy, the Army advances its soldiers to fill vacancies in the next higher pay grade within a given community, which gives rise to considerable variation in the advancement rates across different ratings. By contrast, the Air Force seeks to advance its most qualified airmen regardless of their rating, leading to little variation in advancement rates across different ratings.

The main results of Buddin et al. (1992) are as follows: (1) using a high school degree as the baseline, individuals with some post-high school education advance to E-5 at a rate of about seven percent faster, whereas individuals with General Educational Development (GED) have comparable advancement times to high school graduates, and non-high school graduates have advancement times approximately 16 percent slower; (2) a 10 percent increase in AFQT score correlates to about a 45 day decrease in a soldiers' expected advancement time; (3) individuals who advance faster to E-4 are also more likely to advance to E-5 in a shorter period of time. Relevant to this thesis, Buddin et al.

(1992) also find, when evaluating advancement times by rating, that advancement times to E-5 in the medical and dental fields are approximately 20 percent slower than for individuals in combat specialties.

For Air Force personnel, Buddin et al. (1992) find that while the percentages and time to advance vary slightly, both an increase in AFQT score and faster advancement to E-4 affect advancement tempo in a manner similar to their findings for the Army. Regarding education, their results indicate that time to advance to E-5 is negligible between individuals with a high school education, GED, and post-high school education. Additionally, while individuals with no high school education have about an eight percent increase in their expected time to advance, they also made note that this statistic is only based on 0.3 percent of Air Force airmen (approximately 37 individuals) falling into this category.

2. Studies on the Effects of Education and AFQT Scores on Advancement Probabilities

Cooke and Quester (1988) formulate a model predicting first-term success for Navy enlistees. Using data collected from the Navy Recruiting Command and Enlisted Master Record file between 1978 and 1982, the authors analyze 171,015 non-prior service male recruits, each with a four year first-term obligation. In order to measure the effectiveness of each recruit, they estimate the following probabilities for a recruit: non-attrition; successful advancement to E-4 prior to reaching 45 months of service; and retention beyond their initial four year commitment. From the original data set, three random samples are generated of approximately 6,000 individuals each, and probit modeling is applied for analysis across each of the three measures of effectiveness for success. The dependent variables associated with recruit characteristics used in the analysis are: a recruit's educational background, broken down by high school graduate, GED, and non-high school graduate; AFQT scores; whether a recruit is enrolled in the Delayed Entry Program (DEP); race (White, Hispanic or African-American); and whether a recruit proceeds directly to an "A" school upon completion of basic training. Sailors are grouped into four main categories: high school graduates with AFQT scores from 49–99; high school graduates with AFQT scores from 10–48; GEDs with AFQT

scores from 49–99; and non-high school graduates with AFQT scores from 10–48. Each of these groups are further broken down into the following sub-groups: “A” school with four months DEP; “A” school without DEP; no “A” school with four months DEP; and no “A” school without DEP. From the results, the authors find that individuals with higher education and AFQT score have a better probability of advancing to E-4. Additionally, they conclude that “consistent with the results of other researchers, this analysis finds that graduation with a high school diploma is a more important indicator of recruit success than aptitude test scores” (Cook and Quester, 1988, p. 9).

In a similar study, Olson and Quester (1988) use data from the Enlisted Master Records, for every non-prior service recruit with a three or four year enlistment commitment between 1978 and 1986. As a measure of success, they use statistical analysis to determine the respective success or failure rates across the following five performance categories: desertion, demotion, attrition within their first term, advancement, and retention.

Similar to the findings of Cooke and Quester (1988), Olson and Quester (1988) show that when measuring recruits’ success rate for advancement to E-3 or above within 12 months, and E-4 or above within 45 months, Sailors with higher education levels and AFQT scores have higher success rates in each of the two categories. The authors also show that high school graduation is a better indicator of success than an individual’s AFQT score.

3. Previous Studies on the HM Community

Using data collected from the Military Entrance Processing Command, Enlisted Master Loss File, and Active Duty Master File between the years of 1979 and 1992, Brower (1995) tracks the career progression of 1,834 first-term naval recruits who enlist into the HM community in 1979. In doing so, he analyzes the process of a hospitalman recruit (E-1; HR) advancing to the rate of HMC, by developing three maximum likelihood logistic regression models, each with its own binary response variable. The models measure the following three outcomes of interest: did an individual advance to the rate of HMC?; did an individual remain in the Navy through the end of the data set?;

and, if an individual did in fact advance to the rate of HMC, were they able to do so within 11 years of service? The independent variables used in this study are: age; race (white, African-American, or Hispanic); AFQT score; dependents; education (non-high school graduate, high school graduate, some college, college graduate, and if they attend college during their military service); gender; and NEC.

The following summary statistics are reported by Brower (1995) to give the reader an idea of the population in the data set, both at their time of entry, and at the conclusion of the study in 1992. The average recruit is found to be a white male, 19 years of age, with a high school degree, mean AFQT score of 53, and no dependents. Of the original 1,834 recruits, only 311 individuals remain in the service in 1992, of which a total of 69 individuals made or surpassed the rate of HMC, with 47 of them having done so by the 11 year mark.

The race, sex, and NEC variables are of particular interest to Brower (1995), and are therefore left in the model for analysis regardless of their statistical significance. Considering the first model, which addresses whether or not an individual advances to HMC, the results show, surprisingly, that of all the independent variables, the only one that has predictive significance is NEC; specifically: HM-8401, search and rescue medical technician; HM-8425, surface force independent duty technician; HM-8432, preventative medicine technician; and HM-8493, medical deep sea diving technician. In analyzing the results with regards to the 47 individuals who make HMC by the 11 year mark, there is not a single variable found to be statistically significant in predicting an individual's advancement probability to HMC with-in the given time restriction.

In another study of the HM community, Jones (1995) uses data provided by the Defense Manpower Data Center of 6,979 first-term HM recruits, with a four-year service agreement to determine the individual characteristics associated with a successful HM. Multivariate logistic regression models are used to identify the statistically significant predictor variables for advancement to HM3. The independent variables used in his analysis are education; AFQT scores; gender; race (white, African-American, or Hispanic); age; marital status; and whether or not they have dependents.

Jones (1995) finds at a 0.05 significance level, that having a high school diploma, higher AFQT score, being married, and having dependents all have positive effects on an individual's probability of advancement to E-4. He also finds the following variables have a negative effect on predicting advancement: being under the age of 19 at enlistment; being enrolled in DEP; and African-Americans are approximately six percent less likely to advance to E-4 compared to their White counterparts. Additionally, the following variables are found to have no significant effect on predicting advancement probabilities: gender; an individual with a GED when compared to a non-high school graduate; and Hispanics when compared to their White counterparts.

B. THE ADVANCEMENT PROCESS FOR ENLISTED PERSONNEL

The *Advancement Manual for Enlisted Personnel of the U.S. Navy and U.S. Navy Reserve* (Bureau of Naval Personnel [BUPERS], 2007) provides guidance to military commands and individual service members by which active duty enlisted personnel serving in the U.S. Navy are to be advanced. Prior to being considered for advancement, a Sailor must first meet time in rate (TIR) and total active federal military service (TAFMS) requirements, which are shown in Table 1 for each enlisted pay grade.

PAY GRADE	TIR	TAFMS
E-2	9 months	6 months
E-3	9 months	1 year
E-4	6 months	2 years
E-5	1 year	3 years
E-6	3 years	7 years
E-7	3 years	11 years
E-8	3 years	16 years
E-9	3 years	19 years

Table 1. Time in rate and total active federal military service requirements for advancement in pay grade (after BUPERS, 2007)

Once a Sailor meets TIR and TAFMS requirements, the next step towards advancement for each respective pay grade is delineated as follows:

> Advancement to E2 and E3. Personnel meeting minimum time-in-rate (TIR) requirements will be advanced automatically to E2 and E3 without local action. A special performance evaluation is not required to document recommendation for advancement. (BUPERS, 2007, p. 1-3)
>
> Advancement to E4 through E7. Advancement candidates E4 through E7 take competitive examinations that are used as part of a FMS. The FMS system is based on knowledge, performance, and experience factors, and considers the "whole person" in its selection criteria. For E7, the FMS is comprised of the examination score and performance evaluations. For E4 through E6, the factors consider a candidate's advancement-in-rate examination score, performance evaluations, service in pay grade, awards, and previous examination performances. (BUPERS, 2007, p. 1-3)
>
> Advancement to Chief Petty Officer (E7), Senior Chief Petty Officer (E8), and Master Chief Petty Officer (E9) by Selection Board Action. Advancement to E7, E8, and E9 requires selection board action. Candidates who qualify for selection board consideration are designated SELECTION BOARD ELIGIBLE (SBE). E7 candidates must be designated SBE by competing in a Navy-wide advancement examination and meeting final multiple requirements for their rate. E8 and E9 candidates are designated SBE on the basis of their CO/OIC recommendation and TIR eligibility. (BUPERS, 2007, p. 1-5)

Table 2 shows the breakdown of calculating a Sailor's final multiple score (FMS) by component for the E-4 and E-5 pay grades. Of note, there are two advancement cycles per year for these pay grades, which occur in March and September.

Factor	Computation	Max Points
Standard Score (SS)	Indicated on Exam Profile Sheet	80 (38%)
Performance	(PMA x 80) – 230	90 (43%)
Service In Pay Grade	SIPG + 7.5	15 (7%)
Awards	Points vary by award	10 (5%)
Pass Not Advanced points	PNA points from last 5 cycles	15 (7%)
Maximum FMS possible		210 (100%)

Table 2. Final multiple score computation (after BUPERS, 2007)

As shown in Table 2, a Sailor's FMS is made up of the following components: a standard score, which is the resultant grade from the in-rate examination; performance, which is calculated by assigning a numeric value to the relative ranking Sailors receive on their evaluation reports and designated as performance mark average (PMA). The

possible ranks are early promote, must promote, promote, progressing, and significant problems, which are given a numeric value of 4.0, 3.8, 3.6, 3.4, and 2.0 respectively; service in pay grade (SIPG), representing the amount of time a Sailor has in their current rate; awards, which assigns varying points for awards a Sailor has earned; and pass not advanced (PNA) points, which rewards Sailors who have previously competed for advancement but did not select by awarding them points based on how they did compared to other Sailors with respect to their previous test and PMA scores.

The advancement exam consists of 200 questions, testing individual Sailors on their in-rate and professional military knowledge. The number of correct answers is converted to a standard score to facilitate comparison among Sailors who took the test. The standard score is on a scale of 20 to 80 points, with 50 points representing the median number of correct responses across all individuals who took the exam for a given cycle. A Sailor must receive a standard score of at least 30 to pass the exam and to be eligible for advancement.

Following an exam cycle, and prior to the results being released, a determination is made as to the number of individuals who will be advanced to the next respective pay grade. This determination is made by the enlisted community manager (BUPERS-32), and occurs approximately two months following an exam cycle. The process consists of calculating the projected manning numbers at the next respective rate over the next nine months, respectively. Using advancement from HM3 to HM2 as an example, the following factors are considered: the current number of Sailors in the HM2 community, including those individuals who previously selected, and are awaiting advancement to petty officer first class (E-6; HM1); as well as the projected number of HM2 losses, per historical data projection. Additionally, HM3s who are slated to be advanced from the previous exam cycle are included in the HM2 manning numbers. Once the projected number is generated, the required number of advancements is determined by calculating the number of individuals necessary to fill the gap, and meet the Navy’s HM2 manning needs (J. Leyden (BUPERS-323), personal communication, March 17, 2014).

Once a Sailor’s standard exam score, along with the number of required advancements is determined for each rate, each Sailor has his or her respective FMS

calculated. Individual FMS scores are then ranked from best to worst for every eligible Sailor of the same respective pay grade and rating. Then, using the determined number of openings at the next rate, the corresponding number of Sailors is advanced, starting with the highest FMS score, and working down the list until the quota is filled. For the purpose of this study, this advancement process will be referred to as the "standard advancement process."

C. HIGH YEAR TENURE AND HM ADVANCEMENT NUMBERS

Implemented in 2012, the current high year tenure (HYT) program is designed to act as force-size management tool by capping the number of years a Sailor is allowed to serve at a given pay grade prior to them being required to separate from the Navy. The idea behind the program is that "by limiting how long Sailors can remain in the Navy, the HYT program increases advancement opportunity for high-performing Sailors across pay grades and length of service (LOS)" (Perez, 2012, para. 4). Table 3 shows the established HYT numbers by pay grade for active duty Sailors, as well as the average time to advancement to each of the respective rates in the HM community.

Pay Grade	High Year Tenure	Average Time To Advance (HM)
E-2	4 Years	.8 Years
E-3	5 Years	1.2 Years
E-4	8 Years	3.2 Years
E-5	14 Years	5.6 Years
E-6	20 Years	10.7 Years
E-7	24 Years	16.8 Years
E-8	26 Years	19 Years
E-9	30 Years	22.4 Years

Table 3. High year tenure and average time to advance for the HM community (after NPC, n.d.)

D. LIMITATIONS AND ASSUMPTIONS

In addition to the standard advancement process, there are a number of other methods by which a Sailor may be advanced, including: The Accelerated Advancement Program; Selections Conversion and Reenlistment Program; meritorious advancements

for recruiting personnel; Atlantic, Pacific, and Shore Sailor of the Year eligible for meritorious advancement; and the Command Advancement Program. For the purpose of this study, it is assumed that all Sailors are advanced by the standard advancement process, and not one of these other methods. Additionally, while award points make up five percent of a Sailor's FMS, for this thesis, we do not consider this as a factor in the prediction models that we develop.

III. DATA AND METHODOLOGY

A. THE DATA

1. Data Summary

The data used in our research is obtained from the U.S. Navy's Enlisted Master File and provided to us by Navy Personnel Research, Studies, and Technology (NPRST). The data provides personal and professional information on 50,269 Sailors in the HM community in the E-3, E-4, E-5, and E-6 pay grades during the years 1996 through 2004. The data gives a snapshot in time of a Sailor's career profile each time there is a change event. Change events include: leaving naval service; demotion in pay grade; transfer into or out of the HM community; change of duty station; re-enlistment; frocking (a Sailor being permitted to wear the insignia of the advanced rate prior to their official advancement date, and receipt of pay); advancement in pay grade, or failure to advance given that individual was eligible for advancement to the next respective rate. The change events of interest in this thesis are when a Sailor either advances or fails to advance.

Using a Sailor's pay grade at which he or she first appear in the data set as a baseline, the data set is comprised of approximately 77 percent E-3s, 10 percent of both E-4 and E-5s, and only three percent E-6s. Additionally, female Sailors make up approximately 28 percent of the total number of individuals in the data set. Table 4 shows the breakdown of Sailors by the pay grade in which they enter the data set.

	E-3 (HN)	E-4 (HM3)	E-5 (HM2)	E-6 (HM1)	Total
Male	27,097	3,601	4,022	1,313	36,033
Female	11,942	1,087	924	283	14,236
Total	39,039	4,688	4,946	1,596	50,269
Percent of Total	77.7	9.3	9.8	3.2	100

Table 4. Distribution of Sailors by the pay grade in which they first appear in the data set used for analysis

2. Data Manipulation and Cleaning

a. Observations Removed From Analysis

In modeling analyses, an individual Sailor’s record of information should be complete in each of the predictor variables. In the case that a record has a predictor variable with a missing or invalid value, that record is removed from our analysis. Other criteria exclusion is applied as well. Table 5 shows the exclusion criteria and their effects on the data used in our analysis.

Data Removed	Number of Sailors	Percentage of the Data Set
Invalid / Missing PMA	5,153	10.25
Invalid / Missing AFQT	4,059	8.07
Sailors Demoted	675	1.34
Other	117	-
Total	10,004	19.66

Table 5. Summary of Sailors removed from the data set. Data is removed incrementally, starting with the first variable and working down the list, while ignoring potential intersections of variables

In reference to Table 5, each predictor variable in the data set is checked for validity, and the following are found to have missing or invalid entries: PMA, AFQT, and the number of vacancies during an exam cycle. Additionally, Sailors who do not have any pertinent advancement information, or those Sailors who experienced a demotion are also excluded from the analysis. We limit our analysis to those Sailors who have not experienced demotions, as they reflect actions on the part of individuals that are beyond our ability to predict, and are unrepresentative of the population as a whole.

With the removal of records from the data set as described above, the remaining data set consists of records for 40,625 Sailors, which is approximately 80 percent of the original 50,269 Sailors. For the purpose of this study, this updated data set is referred to as the “working data set,” which is summarized in Table 6.

	E-3 (HN)	E-4 (HM3)	E-5 (HM2)	E-6 (HM1)	Total
Male	22,305	2,505	3,118	919	28,847
Female	10,119	770	699	190	11,778
Total	32,424	3,275	3,817	1,109	40,625
Percent of Total	79.8	8.1	9.4	2.7	100

Table 6. Distribution of Sailors by the pay grade in which they first appear in the working data set

b. Grouping Categorical Data

For each categorical variable included in the analysis, we ensure that there is a sufficient number within the categories prior to using it as a predictor variable. For the purpose of defining these variables, each category must contain at least five percent of the working data set. Categories with fewer than five percent are combined into an "others" category for that categorical variable.

c. Designation of Data Subsets for Cross-Validation

In order to maintain the integrity of the analysis and test the fitted models' predictive power, the working data set is randomly split into two groups. The first group consists of 75 percent of the working data set and is designated for model fitting. The second group consists of the remaining 25 percent and is designated for model evaluation. This methodology of creating a main and test data set is done to remove bias when evaluating a model's predictive power, which will occur if the same Sailors are used to both build and test the predictability of a model.

3. Assumptions and Limitations of the Data

One of the goals of this study is to analyze the processes of governing and predicting advancement probabilities in order to provide valuable insights for future use. Specifically, it is the aim of this study that the modeling techniques used here in should apply to future force structure shaping, and advancement probability models. Therefore, an underlying assumption in our analysis is that the data can be regarded as a random sample from a larger population of interest; namely, all HNs and HM3s eligible for advancement. For the pay grades of E-3 through E-6, the data used in this study

represents an exhaustive snapshot of individual Sailors in the HM community from 1996 through 2004. We assume that randomness arises from the advancement process, and that insights gained from the data on this process are applicable generally to Sailors in the medical rating.

In some cases, the data shows that a Sailor is frocked, and then subsequently became eligible for advancement to the same rate. For these cases, which occur in approximately five percent of the working data set, Sailors are classified as having successfully met the criteria for advancement at the time of frocking, and any subsequent attempts at advancement are not considered.

For Sailors who enter the study at a given pay grade, it may not be possible to determine the number of attempts required to advance to the next higher rate; therefore, we exclude them from this respective analysis. Similarly, if a Sailor does not advance within the timeframe covered by the data set, that Sailor is excluded from fitting the respective advancement probability model. This does not preclude that Sailor from being included in other models, as long as the data exists to support their inclusion.

4. Variables Used in the Analysis

Table 7 shows the variables considered in the analysis.

Variable	Type	Description
Promote	Response	Sailor’s advancement status (1 = True, 0 = False)
AFQT	Numerical	Sailor’s AFQT score
EDU	Categorical	Educational level: some high school; high school graduate; some college; bachelor’s degree; associate degree; master’s degree; doctorate
Location	Categorical	Sailor’s location: Fleet concentration areas (Norfolk, Jacksonville, New London, san Diego, Hawaii, Pacific Northwest, Lemoore, Brunswick, Corpus Christi, Gulfport, Port Hueneme); non-fleet concentration area; international
LOS	Numerical	Sailor’s length of service
NEC	Categorical	Sailor’s Navy enlisted classification code
PMA	Numerical	Sailor’s performance mark average
PNA	Numerical	Sailor’s pass not advanced points
PropProm	Numerical	Proportion: number of vacancies at the next respective pay grade, divided by the number of Sailors eligible for advancement
PropSea	Categorical	Proportion of a Sailor’s career deployed at sea: less than 0.25; 0.25 to 0.50; more than 0.50
SeaMonths	Numerical	Total number of sea months a Sailor has
TIR	Numerical	Sailor’s time in rate for a given pay grade
WhatLook3_4	Categorical	The number of attempts a Sailor requires to be advanced from E-3 to E-4
Year	Categorical	The year of the event change where a Sailor either advances or fails to advance

Table 7. Description of the variables used in the analysis

B. METHODOLOGY

1. Multivariate Logistic Regression

In order to evaluate the data in this study, a determination must be made on whether there is a statistical relationship between the independent variables and the dependent (response) variable. Here, the response variable is dichotomous, represented by 0 for failure, and 1 for advancement. Multivariate logistic regression models are often used for modeling a dichotomous response (Hosmer and Lemeshow, 2000).

In a logistic regression model, the binary response variables Y are modeled as independent Bernoulli variables, where the probability of advancement $\pi(X)$ is a function of the k independent variables $X = \{x_1, x_2, ...x_k\}$ through the linear predictor η:

$$\eta = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_k x_k,$$

where $\beta = \{\beta_0, \beta_1, ..., \beta_k\}$ are coefficients associated with the independent variables. In particular, for logistic regression, the probability of advancement is linked to the linear predictor through the logistic link function:

$$\mathrm{logit}[\pi(\mathrm{X})] = \ln\left[\frac{\pi(X)}{1-\pi(X)}\right] = \eta. \tag{1}$$

From (1), we see that the probability of advancement can be expressed as:

$$\pi(\mathrm{X}) = \frac{\exp(\eta)}{1+\exp(\eta)}. \tag{2}$$

The inverse logistic function of (2) serves to map the linear predictor to $[0,1]$, which is the appropriate scale for a probability.

a. Assessing Nonlinearity with Broken Stick Regression

In using logistic models in this thesis, the possible issue of nonlinearity in some of the predictor variables must be considered. To account for this possibility, broken stick regression is utilized in our analysis. According to Helvin, Webber and White, "Broken stick regression is the modeling of two or more intersecting straight lines with the knots (break points) forming the piecewise linear regression either identified prior to data collection based on theoretical consideration or break points identified in exploratory analyses" (Helvin, Webber, and White, 2008). In essence, broken stick regression allows for the identification of a nonlinear relationship between a predictor variable and the response variable through nonparametric means, thus, not first requiring the specification of what that relationship is. For the purpose of this thesis, the breaking point used in each

of the numeric predictor variables is the median value. Although not perfect, we should be able to mitigate many forms of nonlinearity in the numeric predictive variables if it is present.

For each instance broken stick regression is tested, a likelihood ratio test is performed to see if there is statistical significance in using this technique, or if the variable has a linear effect and should be left in its original state. Specifically, the likelihood ratio test compares two models; the first of which contains the variable untransformed; and the second of which uses the upper and lower broken stick functions in its place. The null hypothesis is that the relationship is linear. Rejecting the null hypothesis at a 0.05 level implies there is reasonable evidence to suggest that there is a statistical difference between the models, and that the broken stick model should be used.

2. Model Validation

a. Goodness-of-Fit Test

Once our models have been generated, we need to determine how well they fit the data. To do this, the Hosmer-Lemeshow (H-L) goodness-of-fit test is conducted on each model (Hosmer and Lemeshow, 2000). To guard against bias, we apply the H-L goodness-of-fit test by applying the models fit to the 75 percent of the data set to predict probability of advancement for the 25 percent of data designated for model evaluation. Ultimately, the H-L goodness-of-fit test partitions the test data sets into deciles, which are based on the predicted probabilities generated from the model being tested. The observed and estimated expected numbers of observations for each decile are used to compute a chi-square test statistic. The null hypothesis for the H-L goodness-of-fit test is that the model tested is a good fit, and therefore, a p-value less than 0.05 results in rejection of the null hypothesis and serves as an indication that the model is a poor fit for the data. Specifically, the H-L test statistic is calculated via the following equation:

$$H-L = \sum_{j=1}^{10} \frac{\left(O_j - E_j\right)^2}{E_j\left(1 - E_j / n_j\right)},$$

where O_j is the number of observed advances in the j^{th} decile; E_j is the estimated expected number of advances in the j^{th} decile; and n_j is the total number of observations in the j^{th} decile. Under the null hypothesis, the resulting test statistic follows an approximate chi-square distribution with eight degrees of freedom.

3. Software Used For Analysis

For the analysis performed in this study, the R programming language is used (R Development Core Team, 2013), and specifically, the car package is utilized for the multivariate logistic regression modeling (Fox and Weisberg, 2011).

IV. RESULTS AND ANALYSIS

A. VARIABLE SELECTION METHOD

In the analysis of data, and the process of modeling, George Box may have put it best when he said “all models are wrong, but some are useful” (Box & Draper, 1987, p. 424). This is an important sentiment to consider when developing statistical models such as logistic regression, because varying the methodologies and criteria for variable selection often results in several models that fit equally well. Despite this, and regardless of the model selection methods used, one must always be cognizant not to overfit a model. Overfitting a model occurs when predictor variables are included that have little or no contribution to the predictive power of the model. Overfitting injects “noise” into the model, and takes away from the ability of the model to accurately identify the relationship between the legitimate predictor variables and the response variable, resulting in a decrease in predictive power.

In order to reduce the effects of overfitting, the models in this study are selected utilizing the Bayesian information criterion (BIC). BIC applies a penalty to the likelihood function associated with the predictor variables included in the model. Specifically, it is “an estimate of a function of the posterior probability of a model being true, under a certain Bayesian setup, so that a lower BIC means that a model is considered to be more likely to be the true model” (Penn State University, 2007, AIC vs. BIC, para. 3). BIC is defined by:

$$BIC = -2\ln(L) - k\ln(n),$$

where, L is the likelihood function, k is the number of predictor variables in the model being evaluated, and n is the number of observations in the data set. Variable selection using BIC balances the apparent improvement with including predictor variables against the penalty associated with them.

B. FIRST LOOK E-3 TO E-4

1. Descriptive Statistics

Of the 13,278 Sailors in the data set that are eligible for advancement from E-3 to E-4, 2,664 advance on their first look. Table 8 shows the descriptive statistics for the five quantitative variables included in the model, including: mean, median, standard deviation, minimum value, and maximum value. Additionally, Table 9 shows the contingency table for the two categorical variables included in the model. As seen in the Table 8, the "average" HN in the data set has: 22.33 months LOS; 1.66 SeaMonths; 0.30 PropProm; AFQT score of 59.41; and 3.75 PMA. In contrast, the "average" Sailor that advances has the following characteristics: 23.68 months LOS; 2.58 SeaMonths; 0.33 PropProm; AFQT score of 65.78; and 3.89 PMA.

Variable	Mean	Median	Standard Deviation	Minimum	Maximum
LOS	22.33	23	6.07	6	100
SeaMonths	1.66	0	2.95	0	27
PropProm	0.30	0.28	0.10	0.07	0.52
AFQT	59.41	57	14.06	35	99
PMA	3.75	3.80	.16	2.00	4.00

Table 8. Descriptive statistics for the quantitative variables: E-3 to E-4 first look data set

Year	Navy Enlisted Classification (NEC) Code			
	0000 (General)	8404 (Field Med)	8701 (Dental Assist)	XXXX (Other)
1996	812	23	155	29
1997	741	611	131	141
1998	469	717	77	116
1999	306	849	87	155
2000	367	913	142	136
2001	573	596	253	103
2002	801	430	221	99
2003	909	444	106	135
2004	905	529	77	120
Total	5,883	5,112	1,249	1,034

Table 9. Frequency distribution of NEC by year of first look from E-3 to E-4

2. Evaluation of the Logistic Regression Model

Figure 1 summarizes the R output of a fitted logistic regression model additive in the variables described in Table 8 and Table 9, for an individual Sailor's advancement probability to E-4 on their first look. In Figure 1, the two categorical variables Year and NEC are included as sets of eight and three binary variables, respectively. For Year, the binary variables (Year1997, Year1998,…, Year2004) are 1 and 0 depending on Year, with Year1996 serving as the baseline. Similarly, the binary variables corresponding to NEC are NECHM-8404(FldMed), NECHM-8701(DentAssist), and NECother, with the NECHM-0000(General) serving as a baseline. For quantitative variables where broken stick regression is utilized, these variables are represented by BL and BU for the lower and upper piecewise linear portions below and above the median, respectively.

```
glm(formula = Promote ~ Year + LOS + NEC + SeaMonths + PropProm +
    AFQT_BL + AFQT_BU + PMA_BL + PMA_BU, family = binomial, data =
    mdata41)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.7801  -0.4936  -0.2462  -0.0935   4.6981

Coefficients:
                        Estimate Std. Error z value Pr(>|z|)
(Intercept)            -4.052822   0.340718 -11.895  < 2e-16 ***
Year1997                0.302227   0.148872   2.030 0.042345 *
Year1998                0.279327   0.154827   1.804 0.071212 .
Year1999               -0.354017   0.166280  -2.129 0.033251 *
Year2000               -0.226051   0.148503  -1.522 0.127958
Year2001               -0.512297   0.176302  -2.906 0.003663 **
Year2002                0.550347   0.178493   3.083 0.002047 **
Year2003               -0.863195   0.162414  -5.315 1.07e-07 ***
Year2004               -1.513221   0.231942  -6.524 6.84e-11 ***
LOS                     0.019955   0.005875   3.397 0.000682 ***
NECHM-8404(FldMed)      0.129413   0.082013   1.578 0.114577
NECHM-8701(DentAssist) -0.364357   0.130531  -2.791 0.005249 **
NECother                0.580515   0.123291   4.709 2.50e-06 ***
SeaMonths               0.111871   0.011144  10.039  < 2e-16 ***
PropProm                5.068220   0.728036   6.962 3.37e-12 ***
AFQT_BL                 0.035188   0.006866   5.125 2.98e-07 ***
AFQT_BU                 0.054873   0.003555  15.437  < 2e-16 ***
PMA_BL                 10.165431   0.514481  19.759  < 2e-16 ***
PMA_BU                 12.115454   0.392228  30.889  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 9939.8  on 9958  degrees of freedom
Residual deviance: 6278.6  on 9940  degrees of freedom
AIC: 6316.6

Number of Fisher Scoring iterations: 6
```

Figure 1. HM3 advancement model output: first look

Referring to Figure 1, “Estimate” are the coefficients for each corresponding predictor variable, and the “Pr(>|z|)” value is the p-values associated with the Wald test for each variable. A p-value of 0.05 or less suggests that the variable is “statistically significant” for inclusion in the model. Using the results from Figure 1, a Sailor’s advancement probability is estimated as:

$$\hat{\pi}(X)=\frac{\exp(\hat{\eta})}{1+\exp(\hat{\eta})},$$

where the estimated linear predictor $\hat{\eta}$ is given by:

$$\begin{aligned}\hat{\eta} = &-4.052822 + .302227x_{Year(1997)} + .279327x_{Year(1998)} - .354017x_{Year(1999)} \\ &- .226051_{Year(2000)} - .512297x_{Year(2001)} + .550347x_{Year(2002)} - .863195x_{Year(2003)} \\ &- 1.513221x_{Year(2004)} + .019955x_{LOS} + .129413x_{NEC(8404)} - .364357x_{NEC(8701)} \\ &+ .580515x_{NEC(other)} + .111871x_{SeaMonths} + 5.06822x_{PropProm} + .035188x_{AFQT\_BL} \\ &+ .054873x_{AFQT\_BU} + 10.165431x_{PMA\_BL} + 12.115454x_{PMA\_BU},\end{aligned}$$

and the predictor variables are represented by $x's$ with self-explanatory subscripts.

To evaluate the model, an H-L goodness-of-fit test is conducted using the 25 percent of data withheld when building the model. Dividing the 3,319 Sailors into deciles by their estimated probability of advancement, Table 10 shows the results of the test. The associated p-value under a chi-square distribution with eight degrees of freedom is 0.44, and we do not reject the null hypothesis that the model fails to describe the data.

Range of Estimated Advancement Probability	(0,.008]	(.008,.016]	(.016,.029]	(.029,.052]	(.052,.089]
n_j	332	332	332	332	332
E_j	1.34	4.01	7.28	13.12	22.64
O_j	0	2	6	10	20

Range of Estimated Advancement Probability	(.089,.136]	(.136,.212]	(.212,.375]	(.375,.626]	(.626,1]
n_j	331	332	332	332	332
E_j	37.14	56.74	94.77	166.14	262.14
O_j	38	55	108	176	267

Table 10. Hosmer-Lemeshow goodness-of-fit test results for E-3 to E-4; first look, where n_j, O_j, E_j, $j = 1,...,10$ are respectively, the test set number of observations, the number of advanced, and the number of estimated expected number of advanced in the j^{th} decile. Associated p-value is 0.44

3. Evaluation of the Predictor Variables

a. Variables Included in the Model

Due to the nonlinearity of the logistic regression model, when evaluating the effect a predictor variable has on predicting advancement probability, no simple effect can be described by changing an estimated coefficient or one of the predictor variables. In order to show the effect each variable has in the model, a notional person is created to establish a baseline. Then, each predictor variable is varied one at a time, with the result compared to the baseline value. For our analysis, the notional Sailor is a general HM (HM-0000), in 2001, with mean values as reported in Table 8 for the quantitative variables.

The estimated advancement probability for the notional Sailor (a general HM, in 2001, with 22.33 months LOS, 1.66 SeaMonths, 0.30 PropProm, AFQT score of 59.41, and 3.75 PMA) is 5.88 percent, with a 95 percent confidence interval of [4.63, 7.44] percent. Table 11 shows the associated changes in estimated advancement probabilities based on the following perturbations to the baseline case: 10 percent increases in LOS, SeaMonths, PropProm, and AFQT; and an increase of PMA to 4.0 (early promote evaluation). Additionally, Table 12 shows the associated changes in predicted advancement probabilities based on the following modifications: change in NEC (HM-8701); a 10 percent decrease in LOS, SeaMonths, PropProm, and AFQT; and a decrease of PMA to 3.6 (promote evaluation).

Variable	Notional	LOS	SeaMonths	PropProm	AFQT	PMA (EP)
NEC (HM-)	0000	0000	0000	0000	0000	0000
LOS	22.33	24.56	22.33	22.33	22.33	22.33
SeaMonths	1.66	1.66	1.83	1.66	1.66	1.66
PropProm	0.30	0.30	0.30	0.33	0.30	0.30
AFQT	59.41	59.41	59.41	59.41	65.35	59.41
PMA	3.75	3.75	3.75	3.75	3.75	4.0
P(advance)	5.88	6.13	5.98	6.77	7.97	53.28
Difference	-	+ 0.25	+ 0.10	+ 0.89	+ 2.09	+ 47.4

Table 11. Effects of increasing predictor variables value on predicted advancement probabilities; first look

Variable	Notional	NEC	LOS	SeaMonths	PropProm	AFQT	PMA (P)
NEC (HM-)	0000	8701	0000	0000	0000	0000	0000
LOS	22.33	22.33	20.09	22.33	22.33	22.33	22.33
SeaMonths	1.66	1.66	1.66	1.50	1.66	1.66	1.66
PropProm	0.30	0.30	0.30	0.30	0.27	0.30	0.30
AFQT	59.41	59.41	59.41	59.41	59.41	53.47	59.41
PMA	3.75	3.75	3.75	3.75	3.75	3.75	3.6
P(advance)	5.88	4.16	5.64	5.78	5.10	4.61	1.31
Difference	-	-1.72	- 0.24	- 0.10	- 0.78	- 1.27	- 4.57

Table 12. Effects of decreasing predictor variables value on predicted advancement probabilities; first look

Based on the results reported in Tables 11 and 12, the model shows that when evaluating the quantitative variables, and based on the largest change in estimated advancement probability, the most influential variable is PMA, followed by AFQT, PropProm, LOS, and SeaMonths. Additionally, Sailors with the HM-8701 NEC have a lower advancement probability when compared to an HM-0000.

b. Effects of Variables Not Considered in the Model

In addition to the predictor variables considered for inclusion in the model, consideration must be given to certain variables excluded from the analysis. Specifically, the variables of gender, race, and marital status may be of particular interest, and therefore we need to ensure that the model adequately accounts for them. To address this, the model is applied to the 25 percent of data withheld for testing, and the numbers of estimated expected and observed advancements are compared for each of these additional variables, by year. Tables 13, 14, and 15 show the corresponding number of estimated expected and observed observations for gender, race, and marital status, respectively. Additionally, using a chi-square test, p-values are calculated for each of these variables to analyze the fit of the model in their presence one at a time. The resultant p-values are 0.72, 0.62, and 0.74, respectively. The associated p-values indicate the model adequately accounts for the effects of these variables despite their exclusion from the model.

Year	Male		Female	
	Estimated Expected	Observed	Estimated Expected	Observed
1996	30.7	44	16.5	17
1997	98.0	105	51.0	55
1998	58.8	61	20.7	17
1999	62.7	59	12.1	14
2000	79.7	82	11.4	11
2001	46.7	44	9.3	8
2002	63.4	66	25.0	29
2003	37.8	41	19.4	13
2004	17.2	13	4.9	3
Total	495.0	515	170.4	167

Table 13. Chi-square test applied to the first look model, accounting for gender; p-value is 0.72

Year	White		African-American		Hispanic	
	Estimated Expected	Observed	Estimated Expected	Observed	Estimated Expected	Observed
1996	33.5	48	4.3	4	6.2	6
1997	96.5	107	17.9	22	24.6	20
1998	41.8	40	11.4	10	12.8	11
1999	40.6	43	12.7	7	10.2	9
2000	43.6	49	13.9	10	12.6	13
2001	24.8	23	10.1	7	13.6	14
2002	37.2	47	18.0	19	18.7	15
2003	32.2	35	8.8	6	10.2	8
2004	11.4	9	3.7	1	3.0	4
Total	361.5	401	100.7	86	112.0	100

Table 14. Chi-square test applied to the first look model, accounting for race; p-value is 0.62

	Single		Married	
Year	Estimated Expected	Observed	Estimated Expected	Observed
1996	34.1	42	13.1	19
1997	106.5	122	42.4	38
1998	61.8	60	17.7	18
1999	62.8	59	12.0	14
2000	76.1	78	15.1	15
2001	45.8	43	10.2	9
2002	65.5	65	22.9	30
2003	39.1	34	18.1	20
2004	15.7	12	6.4	4
Total	507.5	515	157.9	167

Table 15. Chi-square test applied to the first look model, accounting for marital status; p-value is 0.74

C. SECOND LOOK E-3 TO E-4

1. Descriptive Statistics

Of the 9,251 Sailors in the data set that have a second look at advancement to E-4, 2,354 are successful. The descriptive statistics and quantitative variables for this group of Sailors are shown in Tables 16 and 17, respectively. As seen in Table 16, the “average” E-3 in the data set has: 3.18 SeaMonths; 0.29 PropProm; AFQT score of 57.85; 3.75 PMA; and 1.53 PNA points. The “average” Sailor who advanced has: 4.50 SeaMonths; 0.32 PropProm; AFQT score of 61.72; 3.85 PMA; and 1.95 PNA points.

Variable	Mean	Median	Standard Deviation	Minimum	Maximum
SeaMonths	3.18	0	5.29	0	33
PropProm	0.29	0.27	0.11	0.07	0.52
AFQT	57.85	55	13.38	35	99
PMA	3.75	3.80	.15	2.08	4.00
PNA	1.53	1.5	.74	0	5.5

Table 16. Descriptive statistics for the quantitative variables: E-3 to E-4, second look data set

Year	Navy Enlisted Classification (NEC) Code			
	0000 (General)	8404 (Field Med)	8701 (Dental Assist)	XXXX (Other)
1997	688	276	164	96
1998	398	438	52	104
1999	278	493	44	125
2000	215	684	66	143
2001	281	650	144	127
2002	564	363	219	122
2003	532	311	180	140
2004	695	413	82	164
Total	3651	3628	951	1021

Table 17. Frequency distribution of NEC by Year of second look from E-3 to E-4

2. Evaluation of the Logistic Regression Model

Figure 2 shows the estimated logistic regression model for an individual Sailor's advancement probability to E-4 on their second look.

```
glm(formula = Promote ~ Year + NEC + SeaMonths + PropProm + AFQT_BL +
    AFQT_BU + PMA_BL + PMA_BU + PNA_BL + PNA_BU, family = binomial,
    data = mdata42)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.6796  -0.5948  -0.2839   0.3430   3.5447

Coefficients:
                        Estimate Std. Error z value Pr(>|z|)
(Intercept)            -2.279753   0.365281  -6.241 4.35e-10 ***
Year1998               -0.517515   0.174914  -2.959 0.003090 **
Year1999               -1.031557   0.196499  -5.250 1.52e-07 ***
Year2000               -0.705021   0.148536  -4.746 2.07e-06 ***
Year2001               -1.205770   0.203848  -5.915 3.32e-09 ***
Year2002               -0.382014   0.210022  -1.819 0.068923 .
Year2003               -2.190503   0.193668 -11.311  < 2e-16 ***
Year2004               -2.429686   0.273033  -8.899  < 2e-16 ***
NECHM-8404(FldMed)      0.189993   0.088824   2.139 0.032437 *
NECHM-8701(DentAssist) -0.677237   0.146149  -4.634 3.59e-06 ***
NECother                0.435220   0.121852   3.572 0.000355 ***
SeaMonths               0.058133   0.007006   8.298  < 2e-16 ***
PropProm                4.261999   0.735042   5.798 6.70e-09 ***
AFQT_BL                 0.015724   0.007524   2.090 0.036631 *
AFQT_BU                 0.036511   0.003968   9.201  < 2e-16 ***
PMA_BL                  6.868893   0.541024  12.696  < 2e-16 ***
PMA_BU                 11.152675   0.517194  21.564  < 2e-16 ***
PNA_BL                  0.670679   0.124498   5.387 7.16e-08 ***
PNA_BU                  1.185872   0.084787  13.986  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 7942.1  on 6938  degrees of freedom
Residual deviance: 5229.1  on 6920  degrees of freedom
AIC: 5267.1

Number of Fisher Scoring iterations: 6
```

Figure 2. HM3 advancement model output: second look

Using the results from Figure 2, the estimated linear predictor is:

$$\begin{aligned}\hat{\eta} = & -2.279753 - .517515x_{Year(1998)} - 1.031557x_{Year(1999)} - .705021x_{Year(2000)} \\ & - 1.20577x_{Year(2001)} - .382014x_{Year(2002)} - 2.190503x_{Year(2003)} - 2.429686x_{Year(2004)} \\ & + .189993x_{NEC(8404)} - .677237x_{NEC(8701)} + .435220x_{NEC(other)} + .058133x_{SeaMonths} \\ & + 4.261999x_{\mathrm{PropProm}} + .015724x_{AFQT\_BL} + .036511x_{AFQT\_BU} + 6.868893x_{PMA\_BL} \\ & + 11.152675x_{PMA\_BU} + .670679x_{PNA\_BL} + 1.185872x_{PNA\_BU}.\end{aligned}$$

Using the 25 percent of data set aside to test the model, the H-L goodness-of-fit test is conducted, and Table 18 shows both the expected and observed number of advancements when dividing the 2,312 Sailors into deciles. The associated p-value under a chi-square distribution with eight degrees of freedom is 0.36, suggesting little evidence the model fails to describe the data.

Range of Estimated Advancement Probability	(0,.013]	(.013,.030]	(.030,.054]	(.054,.091]	(.091,.151]
n_j	232	231	231	231	231
E_j	1.45	5.03	9.52	16.33	27.44
O_j	2	3	7	12	23

Range of Estimated Advancement Probability	(.151,.229]	(.229,.345]	(.345,.511]	(.511,.706]	(.706,1]
n_j	231	231	231	231	232
E_j	42.43	64.85	98.16	139.49	192.09
O_j	39	54	97	132	186

Table 18. Hosmer-Lemeshow goodness-of-fit test results for E-3 to E-4; second look, where n_j, O_j, E_j, $\text{j} = 1,...,10$ are respectively, the test set number of observations, the number of advanced, and the number of estimated expected number of advanced in the j^{th} decile. Associated p-value is 0.36

3. Evaluation of the Predictor Variables

a. Variables Included in the Model

To evaluate the effects a predictor variable has on estimated advancement probability, using the mean values shown in Table 16, the notional Sailor in 2001 has an advancement probability of 9.48 percent, with a 95 percent confidence interval of [7.44, 12.01] percent. Varying SeaMonths, PropProm, AFQT, and PNA by 10 percent, as well as PMA to an early promote and promote evaluation, Tables 19 and 20 show the effects

of increasing and decreasing the variables independently on estimated advancement probability, respectively.

Variable	Notional	SeaMonths	PropProm	AFQT	PNA	PMA (EP)
NEC (HM-)	0000	0000	0000	0000	0000	0000
SeaMonths	3.18	3.51	3.18	3.18	3.18	3.18
PropProm	0.287	0.287	0.316	0.287	0.287	0.287
AFQT	57.85	57.85	57.85	63.63	57.85	57.85
PNA	1.53	1.53	1.53	1.53	1.68	1.53
PMA	3.75	3.75	3.75	3.75	3.75	4.00
P(advance)	9.48	9.64	10.58	11.46	11.16	57.27
Difference	-	+ 0.16	+ 1.10	+ 1.98	+ 1.68	+47.8

Table 19. Effects of increasing predictor variables value on predicted advancement probabilities; second look

Variable	Notional	NEC	SeaMonths	PropProm	AFQT	PNA	PMA (P)
NEC (HM-)	0000	8701	0000	0000	0000	0000	0000
SeaMonths	3.18	3.18	2.87	3.18	3.18	3.18	3.18
PropProm	0.287	0.287	0.287	0.258	0.287	0.287	0.287
AFQT	57.85	57.85	57.85	57.85	52.06	57.85	57.85
PNA	1.53	1.53	1.53	1.53	1.53	1.38	1.53
PMA	3.75	3.75	3.75	3.75	3.75	3.75	3.60
P(advance)	9.48	5.05	9.32	8.48	8.27	8.51	3.52
Difference	-	- 4.53	- 0.16	- 1.0	- 1.21	- 0.97	- 5.96

Table 20. Effects of decreasing predictor variables value on predicted advancement probabilities; second look

Table 19 shows the biggest increase in estimated advancement probability results from an increase in PMA, followed by AFQT, PNA, PropProm, and SeaMonths. Whereas Table 20 show the biggest decrease in estimated advancement probability occurs from a decrease in PMA, HM-8701 NEC, AFQT, PropProm, PNA, and SeaMonths.

b. *Effects of Variables Not Considered in the Model*

Evaluating the excluded variables of gender, race, and marital status, Tables 21, 22, and 23 shows the corresponding number of expected and observed observations, by

year. The associated p-values for gender, race, and marital status are 0.84, 0.95, and 0.83, respectively; indicating that despite their exclusion, the model adequately accounts for these variables.

	Male		Female	
Year	Estimated Expected	Observed	Estimated Expected	Observed
1997	81.7	72	47.2	52
1998	44.8	47	21.1	18
1999	48.9	48	18.0	13
2000	81.8	73	19.2	14
2001	57.6	46	12.8	14
2002	70.8	63	25.9	25
2003	25.9	27	11.5	13
2004	22.5	22	7.0	8
Total	434.1	398	162.7	157

Table 21. Chi-square test applied to the second look model, accounting for gender; p-value is 0.84

	White		African-American		Hispanic	
Year	Estimated Expected	Observed	Estimated Expected	Observed	Estimated Expected	Observed
1997	77.7	75	22.7	19	15.1	16
1998	33.2	31	7.7	7	14.2	14
1999	33.7	33	10.6	10	15.8	13
2000	40.4	38	21.0	16	24.9	20
2001	35.0	35	10.9	5	11.1	9
2002	45.9	39	15.5	14	15.0	14
2003	19.1	24	9.6	10	5.0	2
2004	14.4	17	4.0	2	6.3	7
Total	299.5	292	102.1	83	107.3	95

Table 22. Chi-square test applied to the second look model, accounting for race; p-value is 0.95

	Single		Married	
Year	Estimated Expected	Observed	Estimated Expected	Observed
1997	77.6	73	51.3	51
1998	43.2	44	22.8	21
1999	45.7	43	21.2	18
2000	78.3	71	22.7	16
2001	54.9	50	15.5	10
2002	73.3	64	23.5	24
2003	26.4	25	11.0	15
2004	19.3	17	10.2	13
Total	418.7	387	178.1	168

Table 23. Chi-square test applied to the second look model, accounting for marital status; p-value is 0.83

D. THIRD LOOK E-3 TO E-4

1. Descriptive Statistics

6,097 Sailors within the data set have a third look at advancement to E-4, of which 2,338 successfully advance. Table 24 shows the descriptive statistics for Sailors on their third look at advancement. For comparison to the mean values shown in Table 24, the "average" Sailor who advances has: 5.55 SeaMonths; 0.28 PropProm; AFQT score of 59.18; 3.87 PMA; and 3.49 PNA points. Additionally, Table 25 shows the categorical variables included in the model.

Variable	Mean	Median	Standard Deviation	Minimum	Maximum
SeaMonths	4.48	0	7.28	0	35
PropProm	0.26	0.27	0.09	0.07	0.52
AFQT	56.48	54	12.77	35	99
PMA	3.79	3.80	.15	2.80	4.00
PNA	2.95	3.0	1.20	0	7.0

Table 24. Descriptive statistics for the quantitative variables: E-3 to E-4, third look data set

Year	Navy Enlisted Classification (NEC) Code			
	0000 (General)	8404 (Field Med)	8701 (Dental Assist)	XXXX (Other)
1997	207	78	52	26
1998	318	204	44	61
1999	259	328	29	94
2000	172	401	30	99
2001	148	468	67	137
2002	305	345	194	112
2003	337	212	179	109
2004	523	300	94	165
Total	2269	2336	689	803

Table 25. Frequency distribution of NEC by Year of the third look from E-3 to E-4

2. Evaluation of the Logistic Regression Model

The logistic regression model for a Sailor's advancement probability to E-4 is presented in Figure 3.

```
glm(formula = Promote ~ Year + NEC + SeaMonths + AFQT + PropProm +
    PMA_BL + PMA_BU + PNA_BL + PNA_BU, family = binomial, data =
    mdata43)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.6989  -0.6446  -0.2522   0.5814   3.7910

Coefficients:
                        Estimate Std. Error z value Pr(>|z|)
(Intercept)            -4.403841   0.472118  -9.328  < 2e-16 ***
Year1998               -0.279579   0.209824  -1.332  0.18271
Year1999               -0.886049   0.225797  -3.924 8.71e-05 ***
Year2000               -0.447689   0.194827  -2.298  0.02157 *
Year2001               -0.661838   0.234840  -2.818  0.00483 **
Year2002                0.532679   0.246145   2.164  0.03046 *
Year2003               -1.130705   0.215252  -5.253 1.50e-07 ***
Year2004               -1.309931   0.274330  -4.775 1.80e-06 ***
NECHM-8404(FldMed)      0.159190   0.103977   1.531  0.12577
NECHM-8701(DentAssist) -1.456049   0.181387  -8.027 9.96e-16 ***
NECother                0.362167   0.134116   2.700  0.00693 **
SeaMonths               0.039972   0.006281   6.364 1.97e-10 ***
AFQT                    0.029380   0.003351   8.769  < 2e-16 ***
PropProm                8.074307   0.965830   8.360  < 2e-16 ***
PMA_BL                  8.391463   0.620317  13.528  < 2e-16 ***
PMA_BU                 11.680054   0.560487  20.839  < 2e-16 ***
PNA_BL                  0.543817   0.076338   7.124 1.05e-12 ***
PNA_BU                  0.874072   0.074978  11.658  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 6037.3  on 4572  degrees of freedom
Residual deviance: 3736.0  on 4555  degrees of freedom
AIC: 3772

Number of Fisher Scoring iterations: 5
```

Figure 3. HM3 advancement model output: third look

From Figure 3, the estimated linear predictor is:

$$\begin{aligned}\hat{\eta} = &-4.403841 - .279579x_{Year(1998)} - .886049x_{Year(1999)} - .447689x_{Year(2000)} \\ &- .661838x_{Year(2001)} + .532679x_{Year(2002)} - 1.130705x_{Year(2003)} - 1.309931x_{Year(2004)} \\ &+ .15919x_{NEC(8404)} - 1.456049x_{NEC(8701)} + .362167x_{NEC(other)} + .039972x_{SeaMonths} \\ &+ .02938x_{AFQT} + 8.074307x_{PropProm} + 8.391463x_{PMA\_BL} + 11.680054x_{PMA\_BU} \\ &+ .543817x_{PNA\_BL} + .874072x_{PNA\_BU}.\end{aligned}$$

Similar to the first two models, an H-L goodness-of-fit test is conducted on the 1,524 individual Sailors within the designated test data set; the results of which are shown in Table 26. Once again, the test suggests there is little evidence that the model fails to describe the data, as indicated by a p-value of 0.10.

Range of Estimated Advancement Probability	(0,.029]	(.029,.067]	(.067,.130]	(.130,.211]	(.211,.317]
n_j	153	152	152	153	152
E_j	2.06	7.00	15.29	26.32	39.60
O_j	3	6	17	33	56

Range of Estimated Advancement Probability	(.317,.468]	(.468,.629]	(.629,.755]	(.755,.884]	(.884,1]
n_j	152	153	152	153	152
E_j	59.54	82.95	105.14	125.16	142.30
O_j	59	88	103	127	144

Table 26. Hosmer-Lemeshow goodness-of-fit test results for E-3 to E-4; third look, where n_j, O_j, E_j, $j = 1,...,10$ are respectively, the test set number of observations, the number of advanced, and the number of estimated expected number of advanced in the j^{th} decile. Associated p-value is 0.10

3. Evaluation of the Predictor Variables

a. Variables Included in the Model

Using the mean values shown on Table 24, the notional third look Sailor in 2001 has an estimated advancement probability of 22.58 percent, with a 95 percent confidence interval of [17.85, 28.13] percent. Tables 27 and 28 show the effects on estimated advancement probability when increasing and decreasing the following variables: SeaMonths, PropProm, AFQT, and PNA by 10 percent; as well as varying PMA to an early promote and promote evaluation.

Variable	Notional	SeaMonths	PropProm	AFQT	PNA	PMA (EP)
NEC (HM-)	0000	0000	0000	0000	0000	0000
SeaMonths	4.48	4.93	4.48	4.48	4.48	4.48
PropProm	0.26	0.26	0.29	0.26	0.26	0.26
AFQT	56.48	56.48	56.48	62.14	56.48	56.48
PNA	2.95	2.95	2.95	2.95	3.24	2.95
PMA	3.79	3.79	3.79	3.79	3.79	4.0
P(advance)	22.58	22.89	26.52	25.61	27.03	77.06
Difference	-	+ 0.31	+ 3.94	+ 3.03	+ 4.45	+54.88

Table 27. Effects of increasing predictor variables value on predicted advancement probabilities; third look

Variable	Notional	NEC	SeaMonths	PropProm	AFQT	PNA	PMA (P)
NEC (HM-)	0000	0000	0000	0000	0000	0000	0000
SeaMonths	4.48	4.48	4.03	4.48	4.48	4.48	4.48
PropProm	0.26	0.26	0.26	0.24	0.26	0.26	0.26
AFQT	56.48	56.48	56.48	56.48	50.84	56.48	56.48
PNA	2.95	2.95	2.95	2.95	2.95	2.65	2.95
PMA	3.79	3.79	3.79	3.79	3.79	3.79	3.6
P(advance)	22.58	6.37	22.27	19.07	19.81	19.90	5.72
Difference	-	- 16.21	- 0.31	- 3.51	- 2.77	- 2.68	-16.86

Table 28. Effects of decreasing predictor variables value on predicted advancement probabilities; third look

Reviewing Table 27, the biggest gain in predicted advancement probability results from an increase in PMA, followed by PNA, PropProm, AFQT, and SeaMonths. Conversely, the biggest loss in predicted advancement probability results from a decrease in PMA, followed by HM-8701 NEC, PropProm, AFQT, PNA, and SeaMonths.

b. Effects of Variables Not Considered in the Model

Tables 29, 30, and 31 shows the expected and observed number of Sailors that advance on their third look, when specifically accounting for gender, race, and marital status, respectively. Using a chi-square test, the associated p-values for the three additional variables are 0.44, 0.78, and 0.38, indicating the model is properly accounting for them.

Year	Male		Female	
	Estimated Expected	Observed	Estimated Expected	Observed
1997	19.4	26	16.9	22
1998	30.2	30	16.8	15
1999	44.7	56	21.4	28
2000	62.2	72	27.1	19
2001	76.4	81	14.0	16
2002	93.9	87	29.6	35
2003	46.4	45	23.3	22
2004	54.1	53	28.8	29
Total	427.4	450	178.0	186

Table 29. Chi-square test applied to the third look model, accounting for gender; p-value is 0.44

Year	White		African-American		Hispanic	
	Estimated Expected	Observed	Estimated Expected	Observed	Estimated Expected	Observed
1997	24.7	31	5.6	10	4.0	4
1998	26.7	27	7.3	3	8.6	8
1999	32.7	40	12.2	16	13.0	18
2000	37.1	31	21.1	21	18.7	22
2001	40.4	40	18.5	21	18.3	22
2002	56.4	60	24.5	22	14.7	15
2003	23.1	23	14.1	9	20.0	21
2004	39.4	41	18.9	20	12.5	13
Total	280.6	293	122.2	122	109.8	123

Table 30. Chi-square test applied to the third look model, accounting for race; p-value is 0.78

	Single		Married	
Year	Estimated Expected	Observed	Estimated Expected	Observed
1997	22.8	26	13.4	22
1998	32.2	28	14.9	17
1999	45.7	52	20.4	32
2000	60.3	60	29.0	31
2001	62.4	64	28.0	33
2002	81.7	80	41.9	42
2003	51.3	47	18.4	20
2004	53.3	55	29.6	27
Total	409.8	412	195.6	224

Table 31. Chi-square test applied to the third look model, accounting for marital status; p-value is 0.38

E. COMPARING THE LOGISTIC REGRESSION E-3 TO E-4 MODELS

Having individually evaluated the first three advancement logistic regression models to E-4, a comparison is made on the common predictor variables. Specifically, SeaMonths, PropProm, and AFQT are analyzed to evaluate how they affect predicted advancement probabilities from one look to another. Figures 4, 5, and 6 graphically show the resultant net change in predicted advancement probability when increasing and decreasing SeaMonths, PropProm, and AFQT, by 10 percent of the respective mean values for each of the three models.

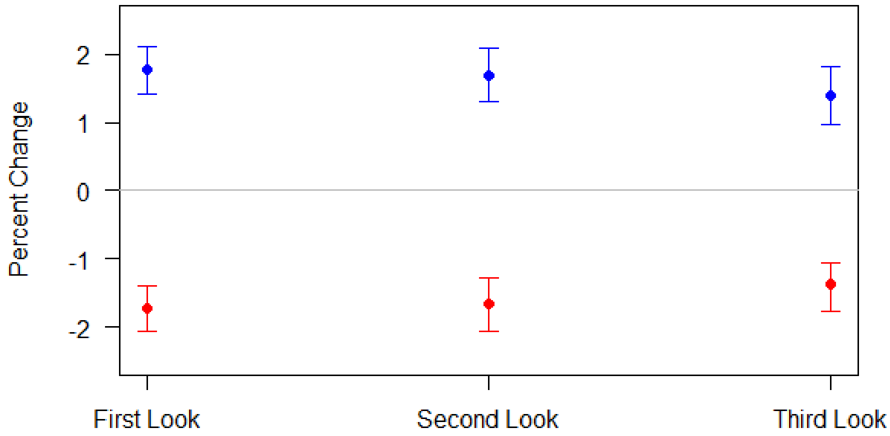

Figure 4. Relative change in the baseline advancement probability when varying SeaMonths by 10 percent of mean values, with associated 95 percent confidence intervals. Blue represents an increase in mean values, whereas red represents a decrease

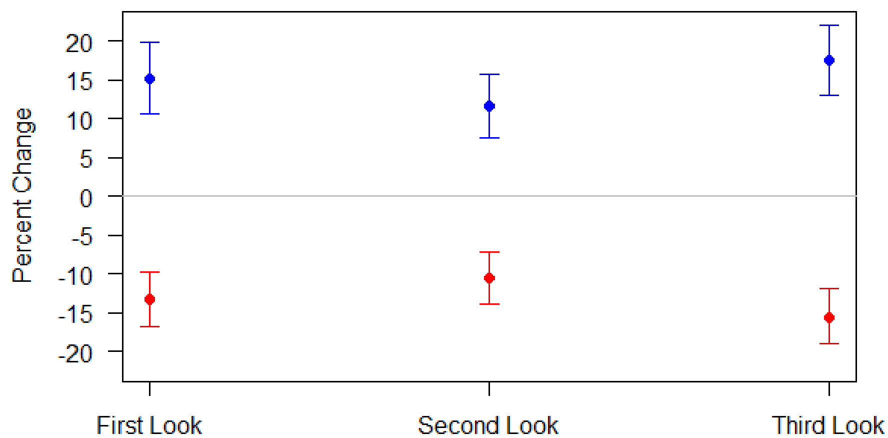

Figure 5. Relative change in the baseline advancement probability when varying PropProm by 10 percent of mean values, with associated 95 percent confidence intervals. Blue represents an increase in mean values, whereas red represents a decrease

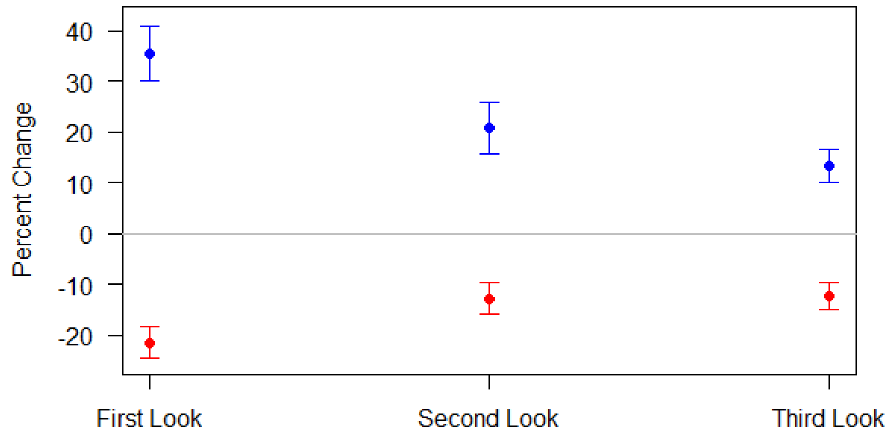

Figure 6. Relative change in baseline advancement probability when varying AFQT 10 percent of mean values, with associated 95 percent confidence intervals. Blue represents an increase in mean values, whereas red represents a decrease

As seen in Figures 4 and 5, the variables SeaMonths and PropProm stay relatively consistent across the three looks in regards to the net change in predicted advancement probability. In contrast, Figure 6 shows that a Sailor's AFQT score has a decreasing weighted effect on advancement probability as a Sailor moves from their first to second, and second to third look at advancement. Intuitively, these results make sense, as we would not expect to see much variation in the effects of increasing and decreasing SeaMonths and PropProm by the same relative amount, from one advancement cycle to the next. Additionally, it makes sense that as a Sailor gains more experience with in a specific rating, acquires prior advancement exam experience, and becomes further removed from taking the ASVAB, their AFQT score would exhibit a smaller weighted effect towards their advancement probability.

F. STUDYING THE EFFECTS OF PRIOR ADVANCEMENT SUCCESS

In order to evaluate whether prior advancement success is a good indicator of future success, logistic regression models are developed for a Sailor's first, second, and third look opportunities for advancement to E-5. Included in the analysis is a new predictor variable, WhatLook3_4. This new categorical predictor variable identifies on which look a Sailor advances to E-4, to see if this information is statistically significant in

predicting a Sailor's advancement success to E-5. In fitting a multivariate logistic regression model, WhatLook3_4 is not statistically significant for inclusion in any of the three models. The associated models and H-L goodness-of-fit test results can be found in the Appendix.

Looking further into the WhatLook3_4 variable, Figures 7, 8, and 9 show the percentage of Sailors that advance to E-5 on their first, second, and third look, respectively; when grouped by how many attempts they require for advancement to E-4. Of note, for Sailors in the data set that do not have information pertaining to their advancement to E-4, they are placed in the unknown attempts group.

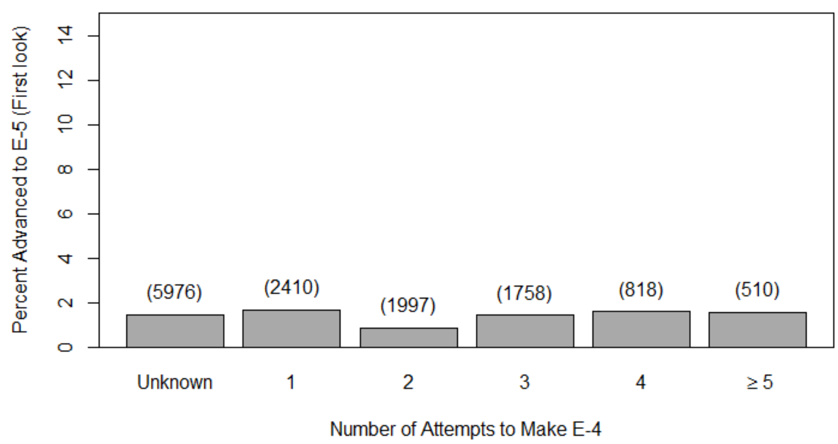

Figure 7. First look E-5 model: distribution of percent advanced by the required number of attempts to advance to E-4. The numbers in parentheses above the bars are the respective sample sizes in each group

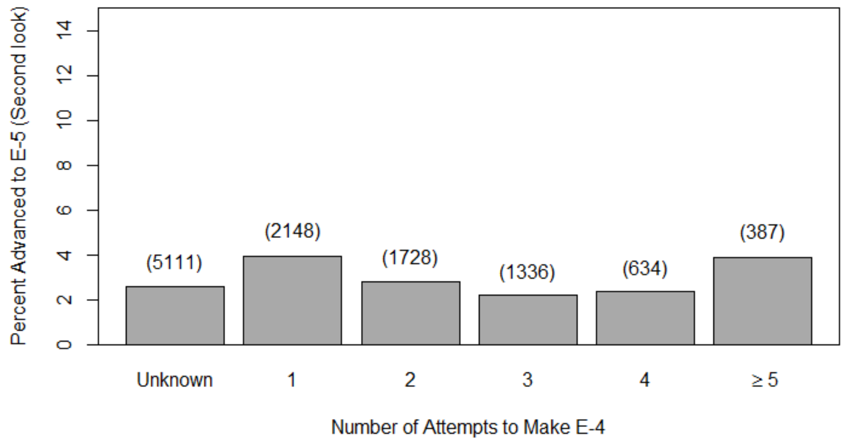

Figure 8. Second look E-5 model: distribution of percent advanced by the required number of attempts to advance to E-4. The numbers in parentheses above the bars are the respective sample sizes in each group

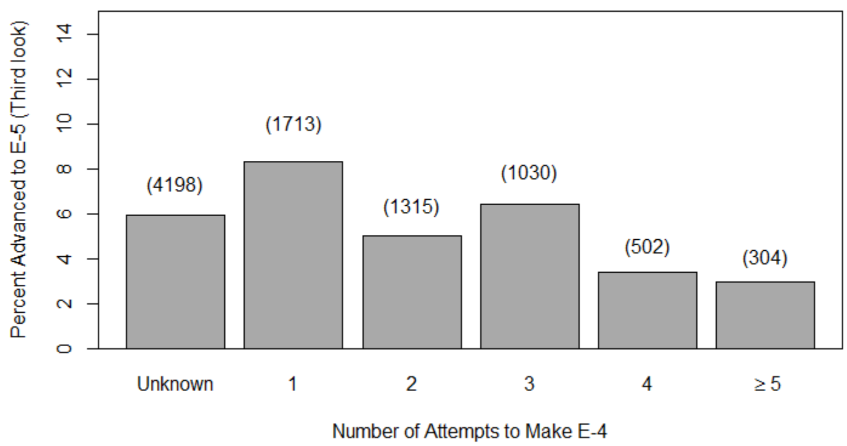

Figure 9. Third look E-5 model: distribution of percent advanced by the required number of attempts to advance to E-4. The numbers in parentheses above the bars are the respective sample sizes in each group

As shown in Figures 7, 8, and 9, there is a fairly even distribution in the percentage of Sailors who advance to E-5 across the groupings of attempts to E-4, for all three advancement looks. This apparently even distribution of advancement percentage is the reason the WhatLook3_4 predictor variable does not appear to have any predictive

power at the HM2 advancement level, and supports this predictor variables exclusion from all three of the E-5 advancement models, as shown in Figures 10, 11, and 12 in the Appendix.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

This thesis develops forecasting models to identify the most influential predictor variables for advancement to E-4 within the HM community. In doing so, we seek to not only forecast advancement rates, but also to compare models so that we can identify similarities across the different looks analyzed. Specifically, three questions are considered in our analysis, which are presented here with our findings. Of note, the findings presented are representative of the predictor variables that have the greatest effects on increasing a Sailor's estimated promotion probability.

1. For Analyzing a Sailor's First Three Looks at Advancement to E-4, Are There Substantial Differences between the Three Models? If So, What Are the Differences?

Comparing the three models, while there is not truly a "one size fits all" model, there are only minor differences in the predictor variables included in the three looks considered. The second and third look models consist of the same seven predictor variables; specifically: Year, Navy enlisted classification (NEC), performance mark average (PMA), AFQT, proportion promoted (PropProm), number of sea months (SeaMonths), and pass not advanced (PNA) points. Conversely, the first look model only differs by the inclusion of length of service (LOS) and exclusion of PNA.

2. What Are the Most Influential Predictor Variables in Determining Probabilities of Advancement to E-4?

As shown in Tables 11, 19, and 27 (Chapter IV), PMA is by far the most influential predictor variable. This makes sense due to PMA making up 43 percent of a Sailor's final multiple score (FMS). AFQT is the second most influential predictor variable for the first two looks at advancement to E-4, however, as shown in Figure 6 (Chapter IV), the weighted effect AFQT has on estimated advancement probability decreases the more looks that a Sailor has. As a result, AFQT is the third most influential variable in the third model. PropProm is the third most influential variable in the first two models, and the second most influential in the third look model. For every model, SeaMonths is the least important predictor variable in estimated advancement rates to

E-4. In addition to these four variables, it is worth noting that PNA has a greater weighted effect on the third model vice the second model. This intuitively makes sense as a Sailor who fails to advance will likely accumulate more PNA points that will be applied on their next advancement cycles FMS calculation.

3. Is Prior Advancement Success a Good Indicator of Future Success? Specifically, Does Knowing on Which Attempt a Sailor Makes E-4 Provide Any Insight on Whether or Not They Will Advance to the Rate of Petty Officer Second Class (E-5; HM2)?

As shown in Figures 10, 11, and 12 (Appendix), the number of looks in progression from HN to HM3 is not found to be statistically significant for inclusion in any of the E-5 advancement models. Additionally, Figures 7, 8, and 9 (Chapter IV) further support their exclusion from the models due to the apparent even distribution of advancement percentage across the WhatLook3_4 groupings. Therefore, the data does not support that knowing the required number of attempts for advancement to E-4 is a good predictor of a Sailor's expected advancement probability to E-5.

B. RECOMMENDATIONS FOR FUTURE WORKS

Based on the analysis performed throughout this study, the following future works are presented for consideration to complement the findings in this thesis. First and foremost, the models and methodologies utilized in this study should be applied to more current data. Doing so will allow for the identification of disparities between the findings based on our data set, vice a more recent sample of U.S. Navy Sailors. Additionally, when developing and analyzing forecasting models, one should always seek to use the most recent data available for analysis. Secondly, we recommend that the methodologies used herein be applied to additional enlisted ratings in the U.S. Navy. In the performance of this analysis, the resultant models developed should lend insight into the different predictor variables, and their associated weights that are influential to advancement across different ratings.

APPENDIX

NEC	TITLE	NEC	TITLE
0000	General Corpsman	8466	Physical Therapy Technician
8401	Search and Rescue Medical Technician	8467	Occupational Therapy Assistant
8402	Submarine Force IDC	8482	Pharmacy Technician
8403	Fleet Marine Force Reconnaissance IDC	8483	Surgical Technologist
8404	Field Medical Service Technician	8485	Behavioral Health Technician
8406	Aerospace Medical Technician	8486	Urology Technician
8407	Radiation Health Technician	8489	Orthopedic Cast Room Technician
8408	Cardiovascular Technician	8493	Medical Deep Sea Diving Technician
8409	Aerospace Physiology Technician	8494	Deep Sea Diving IDC
8410	Bio-Medical Equipment Technician	8496	Mortician
8416	Nuclear Medicine Technologist	8503	Histopathology Technician
8425	Surface Force IDC	8506	Medical Laboratory Technician
8427	Fleet Marine Reconnaissance Corpsman	8541	Respiratory Therapy Technician
8432	Preventive Medicine Technician	8701	Dental Assistant
8434	Hemodialysis Technician	8702	Advanced Dental Assistant
8437	Opthalmic Surgical Technician	8708	Dental Hygienist
8451	Basic X-Ray Technician	8752	Dental Laboratory Technician, Basic
8452	Advanced X-Ray Technician	8753	Dental Laboratory Technician, Advanced
8454	Electroneurodiagnostic Technologist	8765	Dental Laboratory Tech, Maxillofacial
8463	Optician		

Table 32. Navy enlisted classification codes for the HM community (after NPC, 2014)

```
glm(formula = Promote ~ TIR + PMA + BU(AFQT) + BL(AFQT), family =
    binomial, data = mdata51)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.0366  -0.1893  -0.1530  -0.1229   3.3870

Coefficients:
              Estimate Std. Error z value Pr(>|z|)
(Intercept) -18.606623   2.617419  -7.109 1.17e-12 ***
TIR           0.097672   0.021264   4.593 4.37e-06 ***
PMA           3.461694   0.670863   5.160 2.47e-07 ***
BU(AFQT)      0.047853   0.008486   5.639 1.71e-08 ***
BL(AFQT)     -0.039630   0.013195  -3.003  0.00267 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 1569.1  on 10101  degrees of freedom
Residual deviance: 1495.5  on 10097  degrees of freedom
AIC: 1505.5

Number of Fisher Scoring iterations: 7
```

Figure 10. HM2 advancement model output: first look

Range of Estimated Advancement Probability	(0,.006]	(.006,.007]	(.007,.008]	(.008,.010]	(.010,.012]
n_j	346	352	312	337	338
E_j	1.40	2.22	2.34	3.01	3.63
O_j	1	3	5	1	2

Range of Estimated Advancement Probability	(.012,.014]	(.014,.016]	(.016,.021]	(.021,.0284]	(.0284,1]
n_j	335	337	338	342	330
E_j	4.25	5.00	6.13	8.27	14.64
O_j	4	5	6	6	5

Table 33. Hosmer-Lemeshow goodness-of-fit test results for E-4 to E-5; first look, where n_j, O_j, E_j, $\mathrm{j} = 1,\ldots,10$ are respectively, the test set number of observations, the number of advanced, and the number of estimated expected number of advanced in the j^{th} decile. Associated p-value is 0.12

```
glm(formula = Promote ~ LOS + TIR + SeaMonths + BL(PMA) + BU(PMA) +
    BL(PNA) + BU(PNA), family = binomial, data = mdata52)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.6419  -0.2493  -0.1759  -0.1342   3.4120

Coefficients:
             Estimate Std. Error z value Pr(>|z|)
(Intercept) -4.364117   0.373722 -11.677  < 2e-16 ***
LOS         -0.023214   0.006758  -3.435 0.000592 ***
TIR          0.074204   0.022036   3.367 0.000759 ***
SeaMonths    0.021939   0.005372   4.084 4.43e-05 ***
BL(PMA)      1.724563   1.628949   1.059 0.289738
BU(PMA)      5.377939   0.868484   6.192 5.93e-10 ***
BL(PNA)     -0.065515   0.230966  -0.284 0.776672
BU(PNA)      0.948498   0.134471   7.054 1.74e-12 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 2200.0  on 8507  degrees of freedom
Residual deviance: 1968.1  on 8500  degrees of freedom
AIC: 1984.1

Number of Fisher Scoring iterations: 7
```

Figure 11. HM2 advancement model output: second look

Range of Estimated Advancement Probability	(0,.007]	(.007,.009]	(.009,.011]	(.011,.013]	(.013,.016]
n_j	284	285	282	284	283
E_j	1.53	2.21	2.71	3.33	4.18
O_j	2	3	2	1	3

Range of Estimated Advancement Probability	(.016,.020]	(.020,.028]	(.028,.040]	(.040,.064]	(.064,1]
n_j	285	282	284	283	284
E_j	5.17	6.71	9.39	14.12	31.11
O_j	4	4	8	18	36

Table 34. Hosmer-Lemeshow goodness-of-fit test results for E-4 to E-5; second look, where n_j, O_j, E_j, $j = 1,...,10$ are respectively, the test set number of observations, the number of advanced, and the number of estimated expected number of advanced in the j^{th} decile. Associated p-value is 0.63

```
glm(formula = Promote ~ Year + NEC + SeaMonths + AFQT + PropProm +
    BL(PMA) + BU(PMA) + BL(PNA) + BU(PNA), family = binomial,
    data = mdata53)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.6377  -0.3113  -0.1857  -0.1222   3.4599

Coefficients:
                        Estimate Std. Error z value Pr(>|z|)
(Intercept)            -5.185344   0.406841 -12.745  < 2e-16 ***
Year1999                0.283894   0.273460   1.038 0.299198
Year2000                0.826255   0.303327   2.724 0.006450 **
Year2001                0.507743   0.285722   1.777 0.075560 .
Year2002                1.553514   0.260784   5.957 2.57e-09 ***
Year2003                1.292676   0.307637   4.202 2.65e-05 ***
Year2004               -0.362957   0.294466  -1.233 0.217727
NECHM-8404(FldMed)     -0.130679   0.153887  -0.849 0.395775
NECHM-8701(DentAssist) -2.147064   0.374456  -5.734 9.82e-09 ***
NECother               -0.270144   0.166368  -1.624 0.104423
SeaMonths               0.014418   0.004472   3.224 0.001266 **
AFQT                    0.012042   0.003768   3.196 0.001394 **
PropProm               -7.187487   2.082536  -3.451 0.000558 ***
BL(PMA)                 3.910479   2.097174   1.865 0.062232 .
BU(PMA)                 7.613074   0.760593  10.009  < 2e-16 ***
BL(PNA)                -0.238482   0.127880  -1.865 0.062197 .
BU(PNA)                 0.960257   0.068095  14.102  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 3152.0  on 6796  degrees of freedom
Residual deviance: 2355.2  on 6780  degrees of freedom
AIC: 2389.2

Number of Fisher Scoring iterations: 7
```

Figure 12. HM2 advancement model output: third look

Range of Estimated Advancement Probability	(0,.005]	(.005,.008]	(.008,.011]	(.011,.014]	(.014,.020]
n_j	227	226	227	226	227
E_j	0.61	1.39	2.05	2.75	3.87
O_j	2	1	3	0	3

Range of Estimated Advancement Probability	(.020,.029]	(.029,.043]	(.043,.076]	(.076,.162]	(.162,1]
n_j	226	226	227	226	227
E_j	5.54	7.82	13.09	25.11	69.71
O_j	5	11	14	22	68

Table 35. Hosmer-Lemeshow goodness-of-fit test results for E-3 to E_4; third look, where n_j, O_j, E_j, $j=1,...,10$ are respectively, the test set number of observations, the number of advanced, and the number of estimated expected number of advanced in the j^{th} decile. Associate p-value is 0.37

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